Scientific-Lossy Compression for Microscopy Data

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**Abstract**

We introduce a new technique for compressing microscopy videos. Our method can achieve far greater compression ratio than widely used compression techniques such as H.264. Our method also achieves better compression than scientific-lossless compression. We argue that our compressed video has the video quality loss no worse than random noise.

**1. Introduction**

The emerging of high-resolution, high-throughput microscopy system is driving the growth of data size, produced by biophysics experiments. Since the growth of data size is faster than the growth of the affordable data size, a compression of microscopy video data necessary.

Commonly used general data compression method such as bzip2 can achieve about XXX percent compression. The compression technique designed for videos can usually yield a smaller compression, about xxx. Common video compression methods are xxx, xxx, xxxx (H.xxx, wavelet?). Previous work has been done on developing a microscopy video compression technique. XXX has done xxx, XXX has done xxx.

Shao et al. developed a correlation-based method in compressing microscopy video data. Their metheod performs the commonly used data much better. The extra compression is gained by pre-processing the video. In the pre-processing, the background pixels are relaced by their temperoal mean. While the foreground part is losslessly compressed. IN order to find the background pixels, they first sued a correlation-based segmentation approach. They discovered that in the existence of convolution between the point spread function and the singal in microscopy video acquisition phase can be used in segmenting foreground and background. The segmentaion result is then refined by mathematical morphology.

Shao et al. evaluated their method by producing the compressed video that can give the same analysis result under analysis. And comparing the file size against the standard compresion. In fact, the constraint of having the compressed data with the same analysis result as the original video has, is not necessary. By considering the fact that the original video is a real signal corrupted by the noise from various sources, the analysis is a result of combination between the real signal and noise. In other words, the analysis result is the result on the singal without noise, perturbed by the noise in someway. If the compressed video can give the analysis result in the noise-purturbed range, it is considered a good lossy compression. Since we can argue that we can do no better than the noisy video. (we cannot remove the noise).

In Shao et al.’s method, in order to get the exact same compression, the result segmentation foreground is expaned by a disk opratior in mathematrical morphorlgoy. A large enough disk can make sure that the pre-processed video has the same analysis result as the original video, but this will make the compression size larger due to the larger foreground regions. If a smaller dilation is allowed, a better compression is expected.

In this paper, we propose a scientific lossy compression method, that modify the Shao et al’s method, it shrinks the dilation size to achieve a better compression size. We also propose two major evaluation methods, to judge if a lossy compressed video is good. The first evalutation is based on statistical argumetns, to tell if the result after the compression is within the distribution of the noisy result in the ststistical sense. The second evaltuaiton maskes use of the routine of measture a universe’s constant: Boltzmann’s contant, and evaltuate the rslut constant value on the compresed video.

The lossy compression method and two major evalutation methods. Section 3 explanied the evaluation theory. Section 4 explains the compression experiments. Section 5 conlcuses and discusses about the future work.

**2. Method**

The lossy method proposed this paper is based on Shao et al. ‘s idea [1]: by lossy store the information in a video that does not impact the scientific analysis, a better compression that is scientificly good can be achieved. In order to do that, an accturate segmentation method is required. Shao et al discovered that by computing the correlation of a pixel intensity overtime between its adjacent pixels and tatke the absolute value, the result is a score that acctualtely suggests the pixel’s foregrouhnd / background property: the higher this score is, the more likely it is a foreground pixel. They explaines that this is because the foreground pixel is covlolved with the point spread function in the miscoscopy image acquisition phase therefore adjacent foreground pixles are always highly correlated. By thresholding onn this socre from correlation, a segmenation can be achieved. Figure [1] shows a score map, verus the ground truth, on a synthetic data.

In their method, there exists a refinenment stage. In the refinement stage, the salty foreground regisons are removed by the mathematical morphology erode operation, since the argument is that the point’ spread function is the reason of high correlation, and then the foreground regions should not smaller than the point spread function. And the small foreground dot / island is due to too- low threshold, and should be removed . Then the result binary map is further processed by the matheatmaila morphoorlgoy dilate operation to dilate the foreground region . The rsason of this step is due mainly to serve the particular scienfidic analysis routine on the video: the point spot tracking. In the tracking routine, the foreground beads are tracked by the disk shape tracker, and the tracker also includes the background regions. In order to get ethe same analysis result, the background area surrounding the foreground area are also losslessly compressed. This is done by the dialation. And the dilsation operator should match the tracker size. In our method, in order to achieve the better compression, we don’t dilate sthat much.

After the refinement stage, we lossy replaced the background by the mean over whole video, while losslelss compressed the foreground.

The whole piplline is shown in figure 2

XXX figure 2

XXXXX intermediate compressjion: further away from foreground , more information throw out??

In our method, the major difference between it and Shao et al’s method is the different dilation size. In our method, the dilation operator;s size does not match the tracker size. In stead, it is set to insure “scientific-good lossy”, which is also defined in this paper. IN the section 3

XXX is there anything I have not put in section 2 that I should put?

**3. Evaluation**

As stated in last section, a better compression can be achieved by having less data losslessly compressed. The problem is that this modification may result in the perturbed analysis result. In this section we define a metric (distance?) to judge if a perdubation result from compression is acceptable.

This section describes two methods of evaluation. The first is based one common analysis: tracking. The second is based on the measurement on Boltzmann constant hence it is more general.

3.1 Tracking-based evaluation

One common analysis that scientists do on microscopy videos is the tracking of moving objects in the video. The moving objects are usually beads that made from polymer attached on cells. The tracking results of beads shows the cell movement, from which the charasterics of the cell can be studied.

One interesting kind of data that can be derived from tracking results is the curve of mean square displacement (MSD). The one MSD value is calculated by averaging the sequare displacement about the mean point of the movement inside a fixed window. With a sequence of increasing window size, a sequene of MSD values can be computed. By plotting the MSD values versus the window size, we obtain a curve. The MSD curve tells information about the the type of cells. [4] By looking at the shape of the curve, a cell’s type of movement can be classified. [4]

In Shao et al.’s paper, their major experiment for evalutating the compressed video quality is to tracking the beads in it can compare it agains the tracking result on the original video. They made sure that the two results are identical, and shows the data reduction achieved.

In our experiment, we make a smaller compressed video which introduced the difference on the compression result. This difference then propagates to the MSD result. We argue that the propagated difference in MSD curve is negnitigble, which cannot be distinguished form the difference introduced by noise. This is called “scientifically acceptable lossy compression”.

Figure xxx shows the idea.

[XXX figure xxx shows the tracking-based lossy compresioon idea]

The term “which cannot be distinguished form the difference introduced by noise” is justified by statistical tests. The detail of experiment on this evaluation and the gained data reduction in the result compression is explained in “Experiment” section.

XXXX the statistiacal argument should be exp

3.2 Constant-based evaluation

Even 3.1 talks a evaluation based on the MSD curve which is a common analysi, it does not reflect all the properites. In this subsection, we introduce another complement analysis, that is considered more general.

XXXX this is still based on tracking, try to get around it .

[4] notices that the Boltzmann constant can be measured by taking videos of beads doing Brownian motion. The constant is then computed from the tracking result. A lossy compressed video will yield a different mearuement on the constant. If the error is within the range of the measurement from various expeirments, then it is not different from random noise, which is acceptable.

fIgure xxx shows the idea of this evaluation

[xxxx figure shows the constant-based evalutation]

XXXXX: define scientific-good lossy.

**4. Experiment**

**Mention that MSD is a measurement of variaon of displacement and the noise can boost it.**

**4.1 tracking-based experiment**

We design two expeirments to measure the perturbation introduced by compressijon and test if it is within the range of the perturbation introduced by noise. The compression size is reported and compared against scientific lossless compression and common compression.

XXX Mention the desnoising effect.

4.1.1 One compressed video versus the noise distribution

xxx paragraph describe the experiment

[xxx] figure showing the experiment process

xxx figure plotting the distribution and the value (curve?) How to visualize …. Error bar?

[XXX] figure with several distributions, each has its own tau.

4.1.2 Comparison between the compression distribution and the noise distribution

xxx paragraph describe the experiment

[xxx] figure showing the experiment process

xxx figure plotting the distribution and the value (curve?) How to visualize …. Error bar?

**4.1.3 compression size**

**4.2 Constant-measure**

xxx paragraph describe the experiment

[xxx] figure showing the experiment process

xxx figure plotting the distribution and the value (curve?) How to visualize …. Error bar?

4.2.1 compression size

xxx table showing the compression size

**5. Denoising Effect**

In the section talking about experiments, there is a stage to add back the synthesized noise so that the tracking result can be more close to the uncompressed video. Without that , the result is more close to the true value and the version without noise, , with the given true tracking reslt .

By considering this, the compression is actually give the denoising on the original data, to make it more close to the underlying truth. In certain cases, it may be preferred.

XXX paragraph describe the denoising effect.

Xxx picture showing the denoising MSD

**6. Conclusion and future work**

xxx Future work?

**References**

[1] compression paper

[2] panoptes paper

[xxx] some compression paper

[3] MSD paper

[4] Boltzmann constant measurement paper